Long Term Life Testing of Satellite Parts and Materials

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Why Conduct Long Term Life Testing?

- **To assure that life sensitive components will meet mission lifetime requirements**
- **To demonstrate mission survivability**
- **To determine useful lifetime**
- **To determine long term behavior**
- **To determine cause of in-flight failures**
- **To develop screening procedures for flight parts**

History of Long Term Life Testing in the Materials Engineering Branch

- **The MEB has been involved in operational life testing for over 18 years**
- **The MEB has life tested**
  - GOES VISSR encoder lamps
  - GOES VAS encoder light emitting diodes
  - EOS-AM MODIS calibration lamps
  - NOAA AMSU-A2 support bearings and
  - MAP HEMT amplifiers

History (continued)

- **The MEB is currently developing a life test for gold contact slip rings and for a new scanning mechanism for the NOAA AVHRR instrument**
- **The MEB has also developed a thermal cycling facility to simulate the thermal environment that is seen in Low Earth Orbit (LEO), including a high-speed apparatus that was used to simulate the failure of the HST thermal blankets and to qualify EOS-AM Solar Array diodes**

GOES VISSR Encoder Lamp Life Test

- **4 of 4 encoder lamps failed after 1 to 18 months of operation on GOES 2 & 3 which resulted in the loss of Earth images**
- **Previous accelerated life tests predicted that the lamps should have last 7 years**
- **MEB life test at actual operating voltages determined true lifetime and failure mechanism**

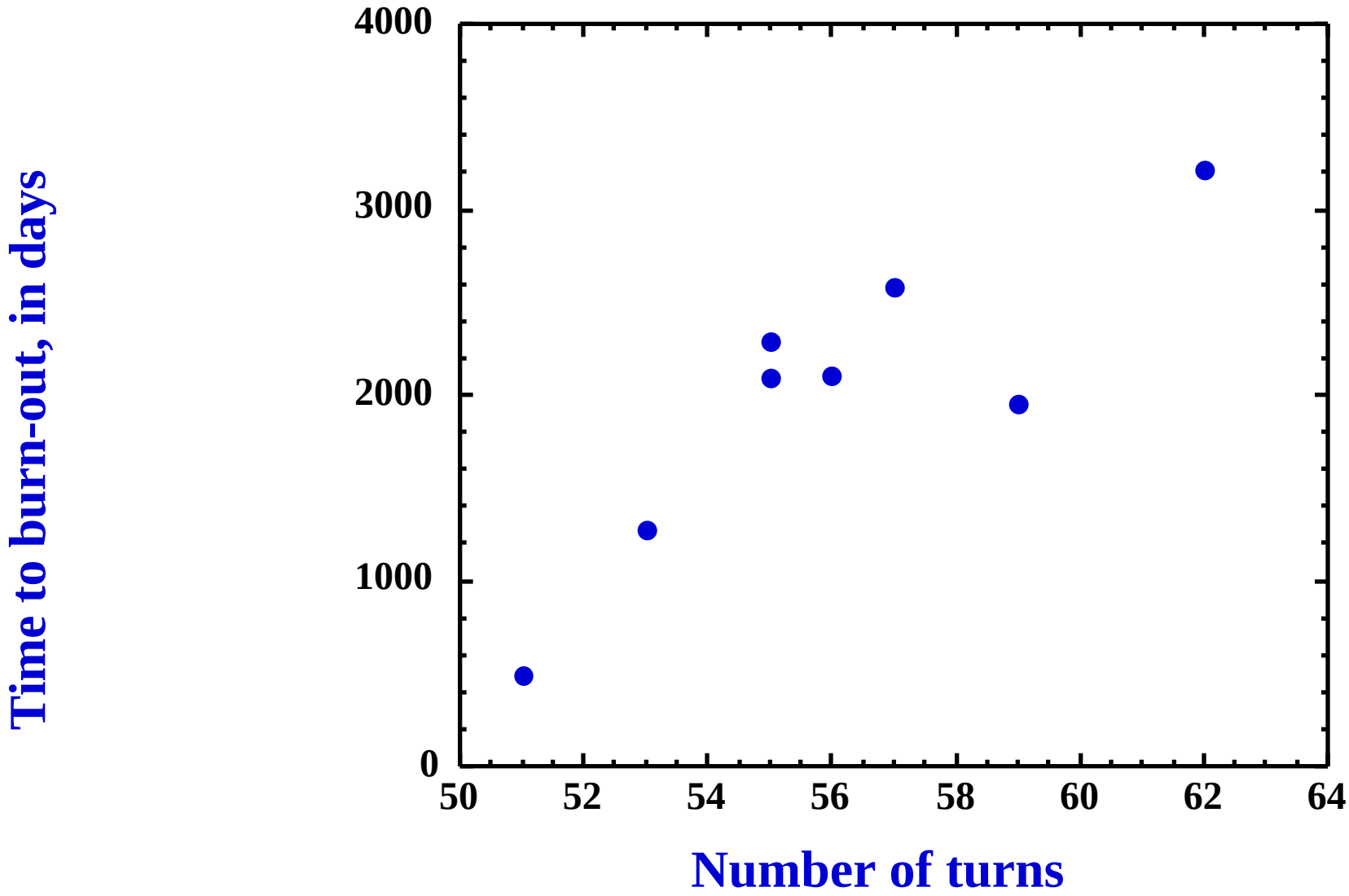
GOES VISSR Encoder Lamp Life Test (continued)

- **Lamp failures were caused by tungsten filament evaporation in the accelerated life test**
- **Lamp failures were caused by tungsten grain growth when tested at actual flight operating voltages**
- **Accurate lifetime predictions made for GOES 5 & 6 from the flight-like life test of 12 lamps (± 1 month of actual lamp failures)**

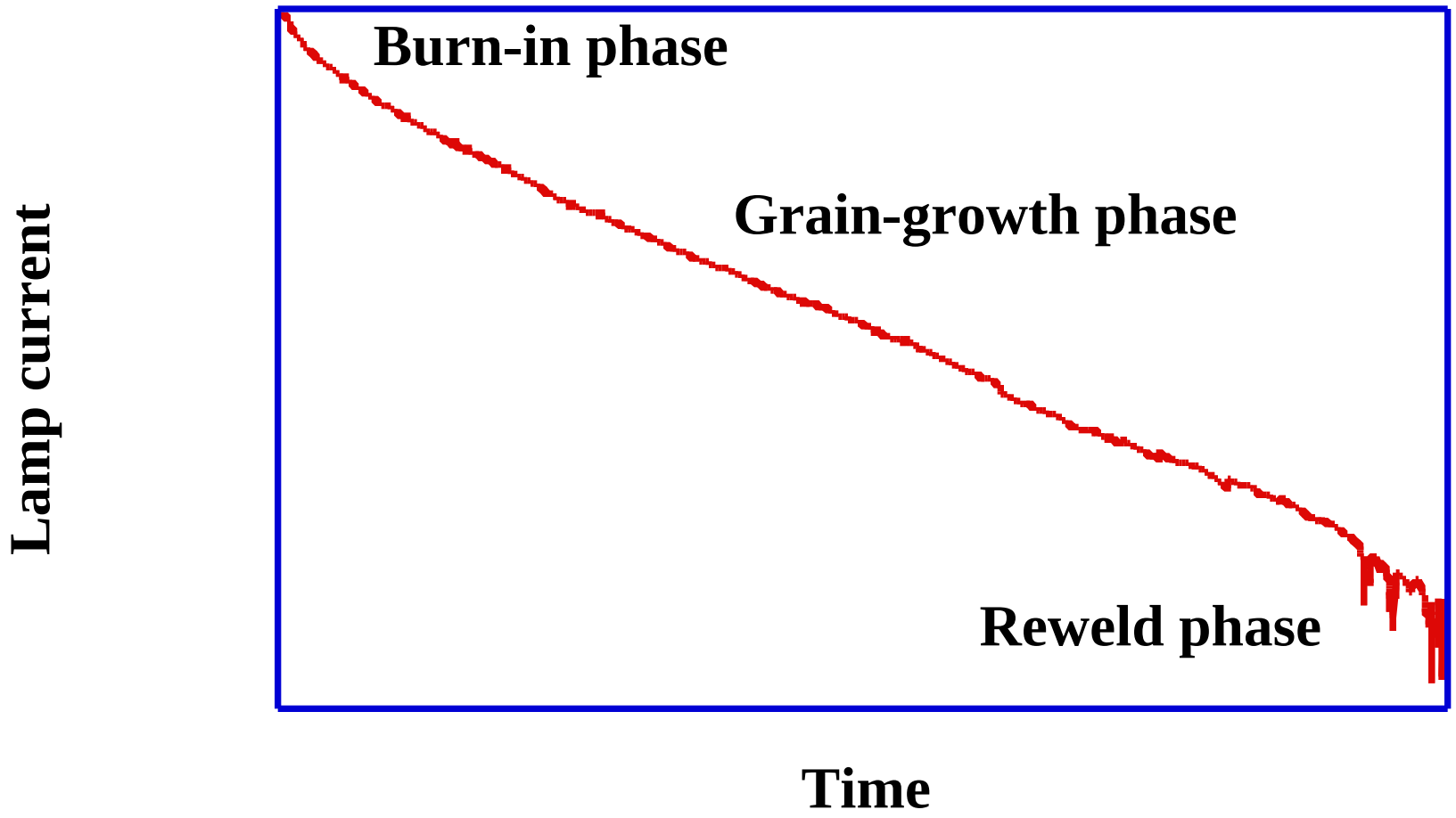
Lessons Learned from GOES VISSR Encoder Lamp Life Test

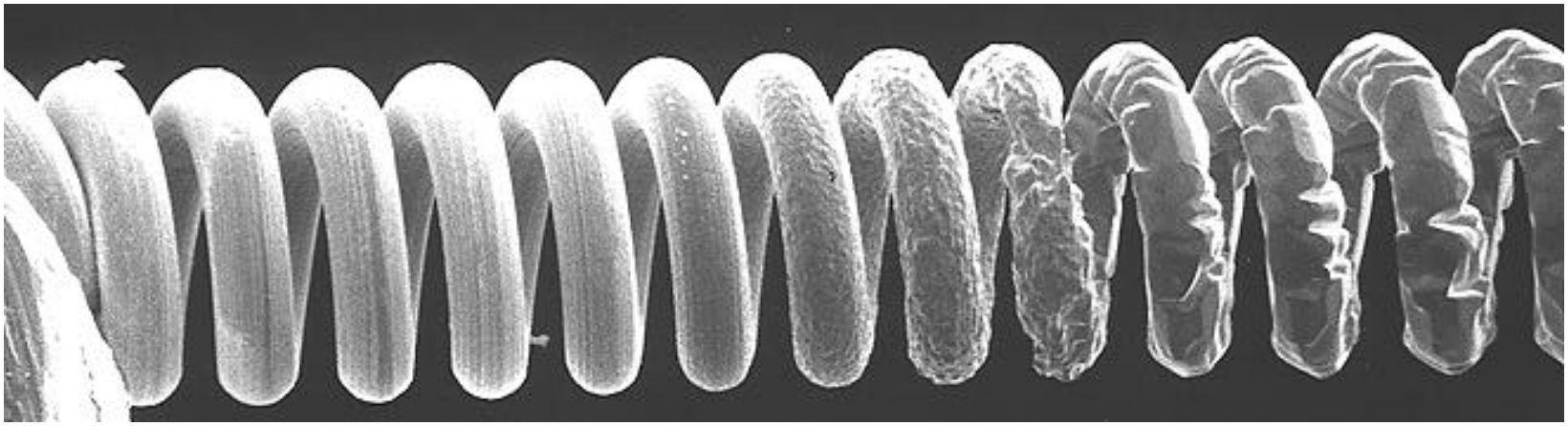
- **Use accelerated life testing cautiously because failure modes can change between accelerated and actual operating conditions**
- **Characterize parts in detail prior to life testing (this determined that the number of turns in a filament has a strong influence on lamp lifetime)**
- **Use automation for monitoring a life test and take lots of data (this allowed us to identify the failure mechanism in the lamps)**

Lamp lifetime vs. number of turns

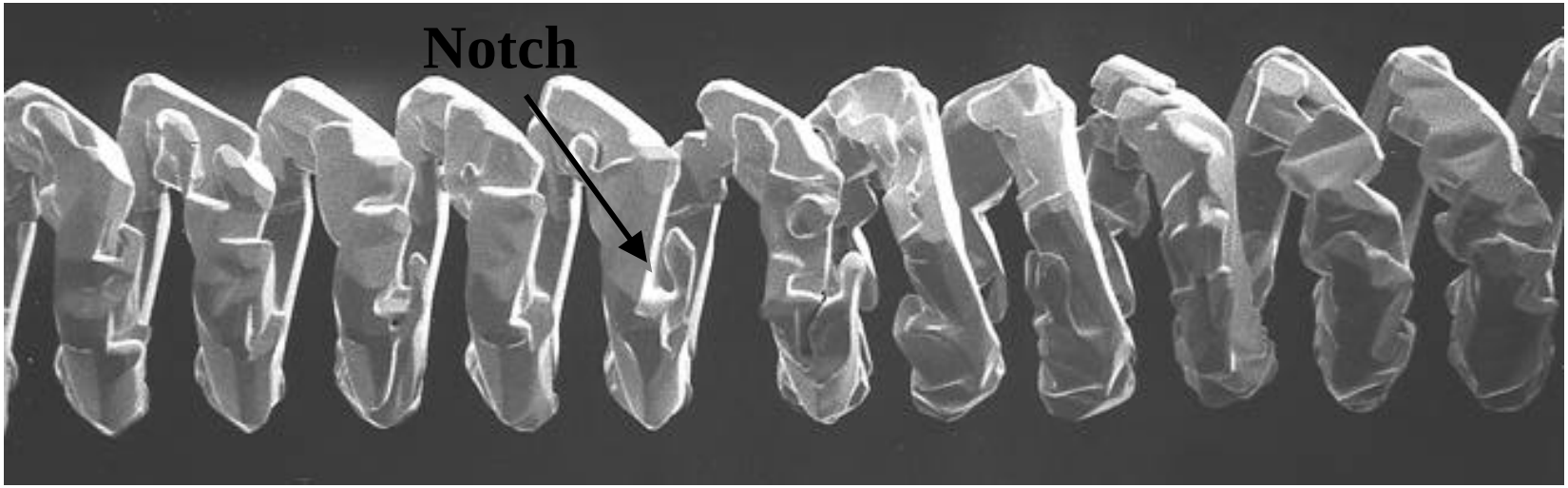


Encoder Lamp Life Cycle





Filament near support post



Center of filament

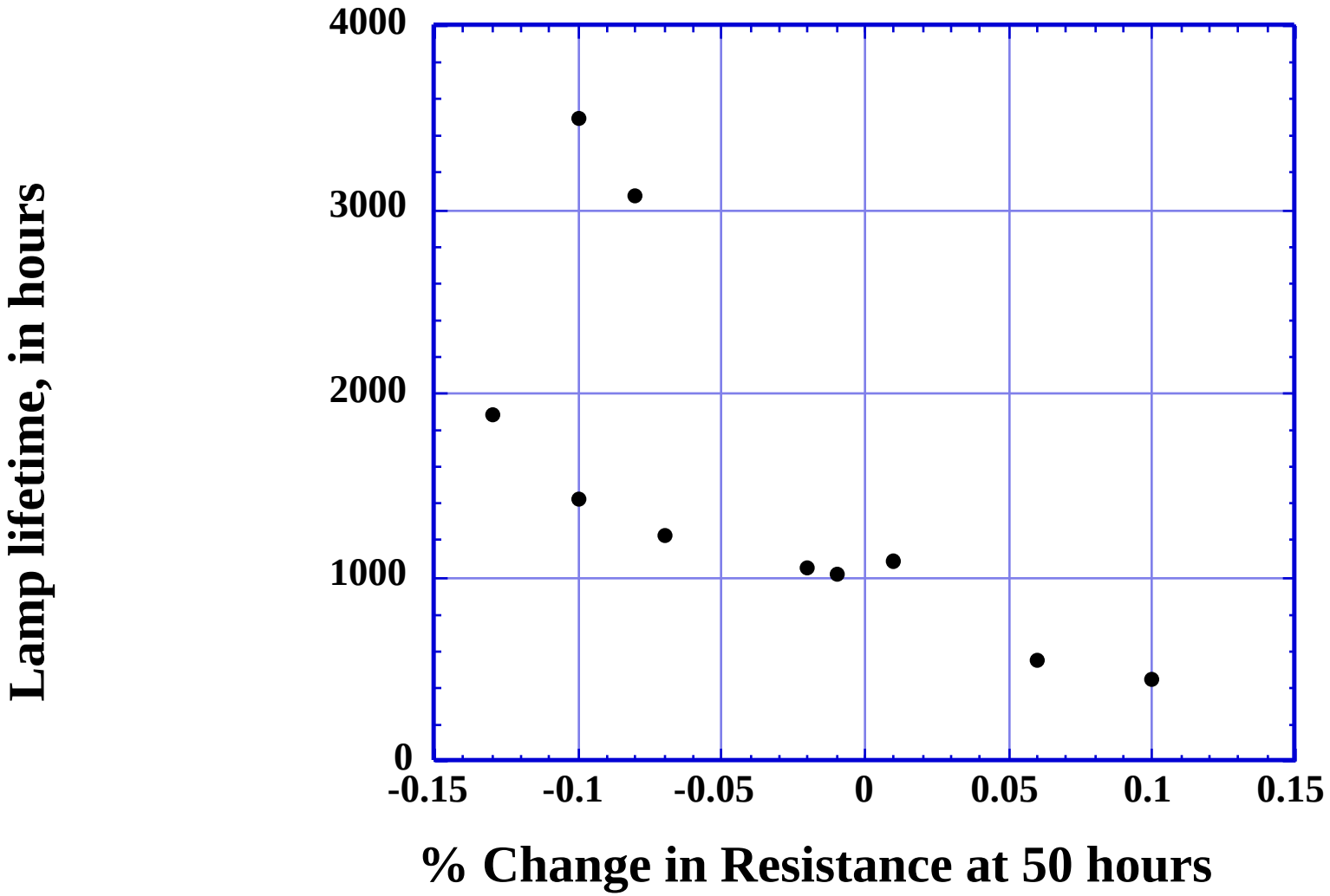
EOS-AM MODIS Calibration Lamp Life Test

- **Life test were initiated to determine the lifetime of Halogen calibration lamps under flight conditions (constant current or constant radiance)**
- **Manufacturer reported average lifetime as 1000 hours at constant 5 volts DC**
- **10 lamps were tested at constant current (2 amperes, initially similar to 5 volts)**

MODIS Calibration Lamp Life Test (continued)

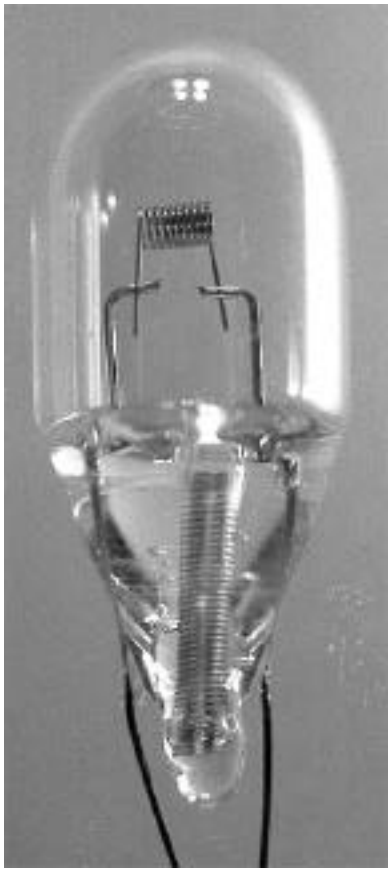
- **Lamp parameters were measured once an hour (voltage, current, light output, temperature)**
- **Periodically, lamp filaments were digitally photographed & time-lapse movies were made near the end-of-life**
- **Life test determined that useful lamp lifetimes ranged from 500 to 3500 hours**
- **Life test also identified a screening method to select longer lived lamps**

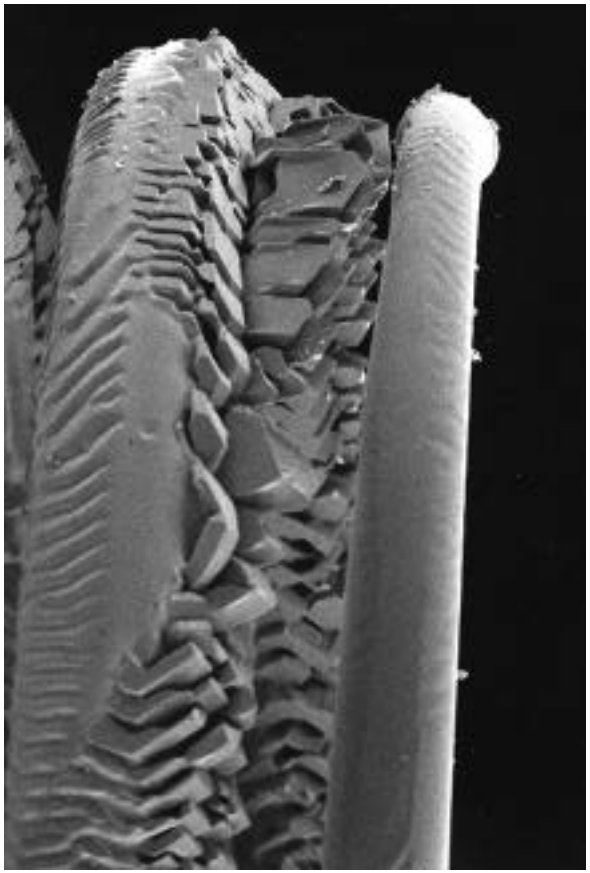
Useful lamp lifetime vs. change in resistance after 50 hours of operation



MODIS Calibration Lamp Life Test also identified failure mechanisms

(open or shorting due to evaporation)





NOAA AMSU-A2 Bearing Life Test

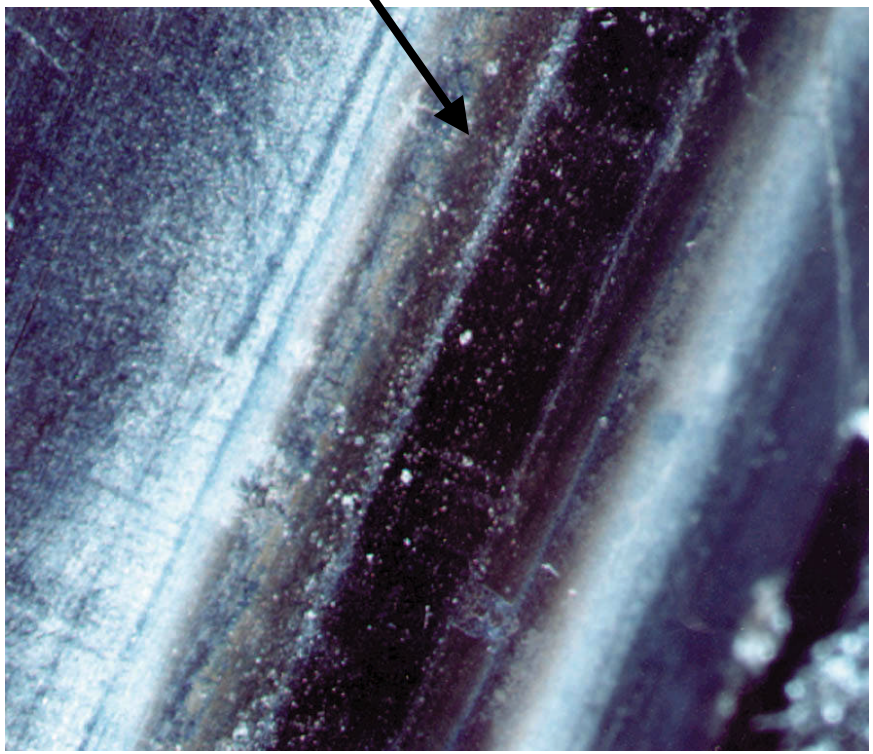
- **Antenna support bearings were identified as a limited life single point failure**
- **The scanning mechanism (including the bearings) completed one revolution every 8 seconds with 32 stop-starts per revolution**
- **Bearings were lubricated with Apiezon C with 5% Lead Naphthenate (LbNp)**
- **Bearings were operating in the boundary lubrication regime, so acceleration was not possible**
- **4 sets of bearings tested for 4.5 to 6.5 years**

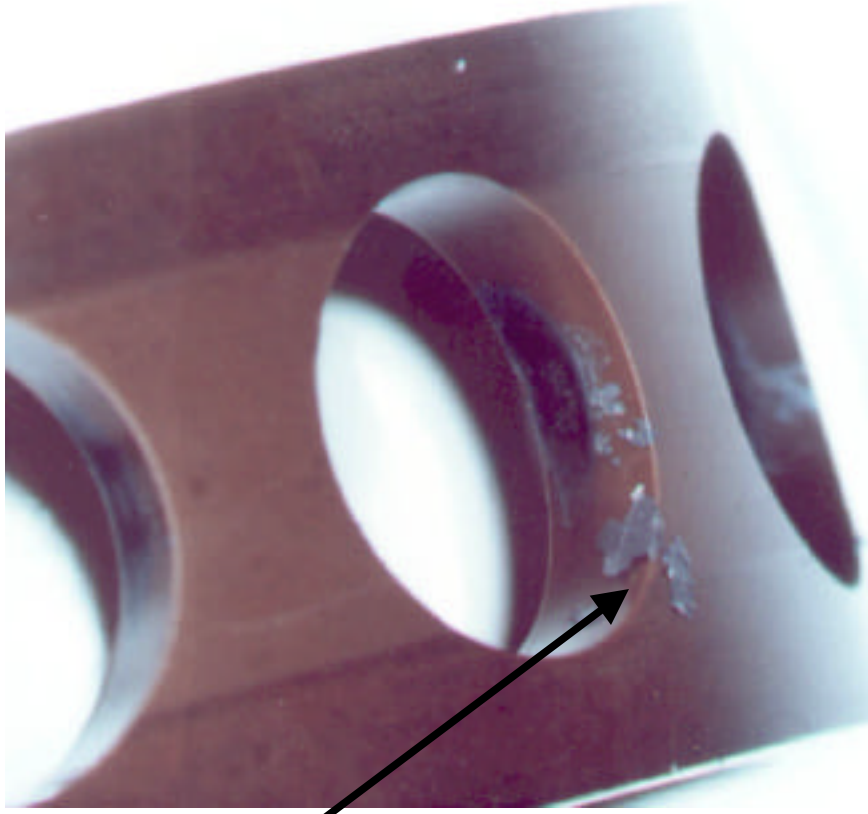
Results of the NOAA AMSU-A2 Bearing Life Test

- **All 4 sets of bearings successfully completed the life test**
- **Bearing torque during the life test had periodic rises and falls (indicating a possible build up of debris or material, followed by break away)**
- **The film build up theory was confirmed by post life test analysis (A LbNp film and debris were found in the bearings)**

NOAA AMSU-A2 Bearing Life Test Post Analysis

PbNp Film





PbNp Flakes

Lessons learned for conducting a long term life test

- **Avoid accelerated testing if you can**
- **If acceleration is your only choice, make sure you understand the failure mechanisms of your part or material**
- **Thoroughly characterize your part prior to life testing (dimensions, defects, IV curves, etc.)**
- **You can conduct a meaningful life test with a small quantity of well characterized parts**

Lessons learned (continued)

- **Instrument as much as you can during the life test**
- **Take lots of data during the life test, especially in the beginning**
- **Automate the data taking and monitoring of the life test**
- **Instrumentation and high data rates can provide an understanding of part behavior and can lead to effective screening techniques**
- **Perform a thorough post life test analysis of parts and materials**

Acronyms

- **AMSU-A2** **Advanced Microwave Sounding Unit, Antenna-2**
- **AVHRR** **Advanced Very High Resolution Radiometer**
- **EOS-AM** **Earth Observing System AM**
- **GOES** **Geostationary Operational Environmental Satellite**
- **HEMT** **High Electron Mobility Transistor**
- **HST** **Hubble Space Telescope**
- **LEO** **Low Earth Orbit**
- **MAP** **Microwave Anisotropy Probe**
- **MEB** **Materials Engineering Branch**
- **MODIS** **Moderate Resolution Imaging Spectrometer**
- **NOAA** **National Oceanic and Atmospheric Administration**
- **VAS** **VISSR Atmospheric Sounder**
- **VISSR** **Visible Infrared Spin-Scan Radiometer**